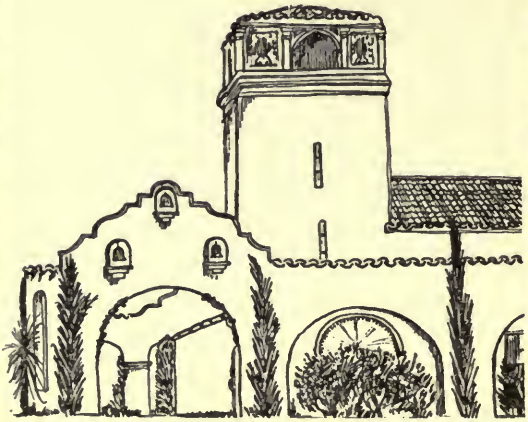
THE INTERVERTEBRAL FORAMINA IN MAN

SWANBERG



THE INTERVERTEBRAL FORAMINA IN MAN

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THE MORPHOLOGY OF THE INTERVERTEBRAL FORAMINA IN MAN INCLUDING A DESCRIPTION OF THEIR CONTENTS AND ADJACENT PARTS WITH SPECIAL REFERENCE TO THE NERVOUS STRUCTURES

(Supplement to "The Intervertebral Foramen")

BY

HAROLD SWANBERG

Member American Association for the Advancement of Science

With an Introductory Note

BY

PROF. HARRIS E. SANTEE

From the Anatomical Laboratory, Chicago College of Medicine and Surgery

Illustrated by 11 original full-page plates

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1915

To My Sister

Marion Goerz Swanberg

THIS BOOK IS

Affectionately Dedicated

INTRODUCTORY NOTE

BY

HARRIS E. SANTEE, A. M., M. D., Ph. D.

MR. HAROLD SWANBERG has enlarged the scope of his contribution to anatomic knowledge by pursuing his investigation to its logical conclusion. His former work, to which I wrote a prefatory note, was done upon the intervertebral foramina of lower animals. That work is fully corroborated and greatly enhanced by the present monograph, which presents an equally careful study of the human intervertebral foramina. In the light of this new knowledge, certain theories of spinal tension and compression must be greatly modified. The undoubted anatomic facts, revealed by Mr. Swanberg in this painstaking, scientific work, necessitate a complete restatement of the rationale of "cures" effected by spinal manipulation.

PREFACE

THE very favorable reception which has been accorded my book, "The Intervertebral Foramen," has stimulated me to further study on this subject. In the above work are found a histologic description and photomicrographs of an intervertebral foramen, its contents and adjacent parts—the first to appear in the literature. The foramen described was taken from a cat. Since the publication of the above I have been in receipt of many inquiries as to whether the description given could be relied upon to be identical with that in man. From the information gained by numerous dissections of intervertebral foramina in man the description given of the foramen in the cat would appear to be similar to that in man. However, in order to scientifically settle this question I made a microscopic study of several intervertebral foramina and their adjacent parts in man. These findings corroborate those described in the original work. While no two intervertebral foramina were found to be identical they all have a similar structure. The above findings were briefly reported in the JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION, Oct. 31, 1914, and the MEDICAL RECORD, Nov. 14, 1914, and later followed by an article entitled, "The Intervertebral Foramina in Man" in the MEDICAL RECORD, Jan. 30, 1915.

In the present text I have endeavored to give a detailed description of the normal morphology of the intervertebral foramina in man, including their contents and immediately adjacent parts. The importance of an intricate knowledge of the morphology of these apertures hardly need be emphasized. During the past quarter of a century a great deal of attention has been directed to the vertebral column from a therapeutical standpoint. Many schools have arisen claiming that the great majority of diseases have their origin from various spinal abnormalities which produce pathologic changes in the intervertebral foramina, their contents, or surrounding tissues. It is not the purpose of this book to argue the case one way or the other but to present, as above mentioned, a clear and concise description of the normal morphology of these apertures and parts in man. Once the normal structure is thoroughly mastered, the reader will then be in a better position to judge for himself the effects of pathologic changes; he can then formulate his own opinion concerning the theories of nerve pressure, irritation, or other pathologic phenomena occurring in the intervertebral foramina or adjacent tissues, as a causative factor in disease.

The Anglicized form of the Basle anatomical terminology (BNA) is used throughout. To facilitate a quick reading of the work the less important details are printed in small type.

Although the work, in general, is entirely original I am indebted to the anatomies of Morris, Gray, Cunningham, and Santee for references.

Zan D. Klopper, M. D., of Chicago, has drawn plates 1, 2, 3 and 5 and did the retouching of the photomicrographs. I have sketched plates 4 and 6.

I desire to express my sincere thanks to my friend and preceptor in anatomy, Harris E. Santee, A. M., Ph. D., M. D., Professor of Neural Anatomy, Chicago College of Medicine and Surgery, for reviewing the work; to William L. Copeland, M. R. C. S., C. M., M. D., Professor and Head of the Department of Anatomy, Chicago College of Medicine and Surgery, for his kindness in supplying material for dissection; to Wayne W. Bissell, B. S., M. D., Resident Pathologist, Cook County Hospital, Chicago, for permission to secure several specimens from autopsies; to Mr. Herbert D. Ulmer for assistance in dissecting; and especially to Mrs. Sarah Jordan Kerns for her invaluable aid in correcting the original manuscript.

CHICAGO, May, 1915.

HAROLD SWANBERG.

PUBLISHERS' INTRODUCTION

The extremely favorable reception which Swanberg's monograph "The Intervertebral Foramen" has received, has been most gratifying. That work, which fills a certain hiatus in the anatomical literature, has been greatly enhanced by the present supplement, which presents for the first time an exhaustive description of the morphology of the human intervertebral foramina, including their contents and adjacent parts.

A few reviews of the original work are appended:

Medical Review of Reviews.

"Swanberg, in a very original and careful volume, establishes the histology of the areas forming the intervertebral foramen. Scientifically accurate, it forms a basic monograph upon the subject it discusses. Original plates, careful explanations, thoroughness in details, and with a most admirable conciseness add to the value of an anatomic study which will be helpful to those interested in the anatomy and histology of the spinal column. . . . . The science of anatomy is replete with similar topics worthy of investigation, and the profession will be fortunate if they are equally ably investigated and reported as has been the intervertebral foramen."

American Journal of the Medical Sciences.

"The investigations of Swanberg emphasize the fact that slight changes in relationship in the spinal structures may give rise to varied symptoms. The work here presented is highly commendable and bears evidence of a thorough and careful investigation. To persons interested in nervous diseases and also in mechanical disturbances of the spine, this book should be of usual interest and value."

Canada Lancet.

"This book is absolutely unique. It is the first and only scientific work on this subject. . . . . This work contains no theories. One can see these parts just as they normally are. You can then formulate your own opinion about nerve pressure, impingement, irritation, etc., as a cause of disease. It is a book every progressive physician should have. To the careful perusal of anatomists everywhere, we have pleasure in introducing this work."

New York Medical Journal.

"It has taken the author four years to complete his researches, and they are therefore of great scientific interest as well as possible therapeutic value. . . . . The book is of value to those interested in the therapeutics of the spine, and the author deserves great credit for his patient investigations in this interesting field."

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THE purpose of this book is to present an accurate and scientific description of the normal morphology of the intervertebral foramina in man, including a complete description of the contents of the foramina and their immediately adjacent parts, with special reference to the nervous structures.

For convenience, the text which follows is divided into three parts:

1. A general description of the intervertebral foramina and their contents.

2. A detailed description of one particular intervertebral foramen and its immediately adjacent parts, with photomicrographs.

3. A summary based upon careful examinations of numerous intervertebral foramina, and their surrounding tissues.

This will give one an excellent idea as to the general structure of all the intervertebral foramina.

PART I

GENERAL DESCRIPTION OF THE INTERVERTEBRAL FORAMINA

I. INTRODUCTION

THE intervertebral foramina are apertures formed by the articulation of two contiguous vertebrae. They serve to transmit spinal nerves, arteries, veins, and in all probability lymphatics.

There are twenty-three pairs of intervertebral foramina extending without interruption from the epistropheus (axis) to the sacrum. Although no two are identical, all have a similar structure. The first pair is situated between the epistropheus and third cervical vertebra and the last between the fifth lumbar vertebra and the sacrum. Spaces or apertures that are not spoken of as intervertebral foramina are found however, between the occipital bone and atlas, the atlas and epistropheus, the rudimentary sacral vertebrae, and the sacrum and coccyx, which transmit spinal nerves and vessels. They may be considered as *modified intervertebral foramina* and will be discussed later.

The intervertebral foramina, like the spinal nerves and vertebrae, are named according to the region of the vertebral column in which they are located, i. e., cervical, thoracic, and lumbar. The following table shows their number in

each region of the column as compared with the number of spinal nerves and vertebrae:

Region	Intervertebral Foramina	Nerves	Vertebrae
Cervical	6 pairs	8 pairs	7
Thoracic	12 "	12 "	12
Lumbar	5 "	5 "	5
Sacral	.....	5 "	5
Coccygeal	.....	1 pair	4
	23 pairs	31 pairs	33

II. BOUNDARIES OF THE INTERVERTEBRAL FORAMINA

The boundaries of the intervertebral foramina have a similar arrangement throughout. Each intervertebral foramen is almost entirely surrounded by bone, the intervertebral fibro-cartilages completing the boundary. The bony boundaries are parts of two adjacent vertebrae, though in the thoracic region the heads of the ribs, from the second to the ninth, inclusive, also assist in forming the boundaries for the first eight thoracic pairs.

The boundaries of the intervertebral foramina are as follows: (Plates 1, 2, 3.)

Anterior.

Cervical, Lumbar, and Twelfth Thoracic	Body of upper vertebra. Intervertebral fibro-cartilage. Body of lower vertebra.
Upper Eight Thoracic	Body of upper vertebra. Head of rib. Intervertebral fibro-cartilage.
Ninth, Tenth and Eleventh Thoracic	Body of upper vertebra. Intervertebral fibro-cartilage.

In the cervical and lumbar regions, the roots of the vertebral arches (pedicles) do not take origin from the extreme upper part of the bodies of the vertebrae. Hence the superior and inferior

vertebral notches are large, though the superior is smaller, especially in the lumbar region. Therefore the cervical and lumbar intervertebral foramina have parts of both adjacent vertebral bodies assisting in forming their anterior boundary.

In the thoracic region the roots (pedicles) take origin from the extreme upper part of the bodies of the vertebrae. Hence the inferior vertebral notches are very large and the superior vertebral notches are only faintly marked. Therefore these intervertebral foramina, with the exception of the twelfth pair, have but a part of one vertebral body assisting in forming their anterior boundary. The twelfth thoracic pair is bounded anteriorly by both the bodies of the twelfth thoracic and the first lumbar vertebrae because of the root of the first lumbar not taking origin from the extreme upper part of the body.

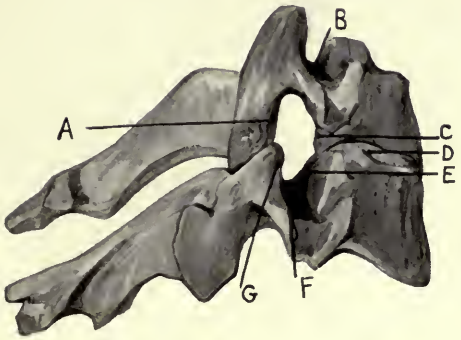
Posterior.

Throughout	Inferior articular process of upper vertebra. Superior articular process of lower vertebra.

The articular processes are held together by a capsular ligament which forms the immediate posterior boundary of the intervertebral foramina. These capsular ligaments, which are composed partly of white fibrous tissue and partly of yellow elastic tissue, are most lax in the cervical and most tense in the thoracic region.

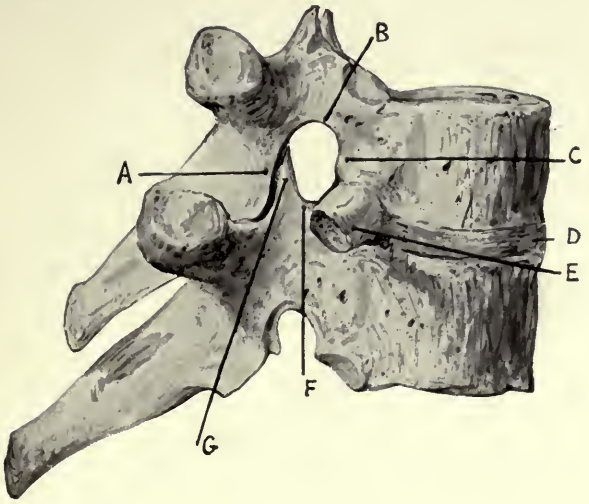
Superior.

Cervical, Thoracic, and Upper Lumbar	Root (pedicle) of upper vertebra.
Lower Lumbar	Root of upper vertebra. Transverse process of upper vertebra.



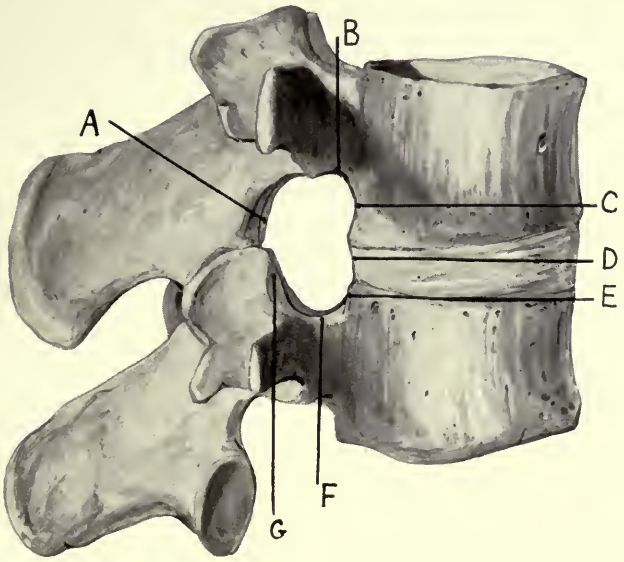
A right lateral view of two adjacent typical cervical vertebrae with the intervertebral fibro-cartilage connecting them. It shows a cervical intervertebral foramen and its adjacent boundaries. Life size. (The vertebrae are the fourth and fifth cervical.)

A—Inferior articular process of upper vertebra.
B—Root (pedicle) of upper vertebra.
C—Body of upper vertebra.
D—Intervertebral fibro-cartilage.
E—Body of lower vertebra.
F—Root (pedicle) of lower vertebra.
G—Superior articular process of lower vertebra.



A right lateral view of two adjacent typical thoracic vertebrae with the intervertebral fibro-cartilage connecting them, and the head of a typical rib articulating with these vertebrae and intervertebral fibro-cartilage. It shows a thoracic intervertebral foramen and its adjacent boundaries. Life size. (The vertebrae are the seventh and eighth thoracic, and the rib the head of the right eighth.)

A—Inferior articular process of upper vertebra.
B—Root (pedicle) of upper vertebra.
C—Body of upper vertebra.
D—Intervertebral fibro-cartilage.
E—Head of rib.
F—Root (pedicle) of lower vertebra.
G—Superior articular process of lower vertebra.



A right lateral view of two adjacent typical cervical vertebrae with the intervertebral fibro-cartilage connecting them. It shows a lumbar intervertebral foramen and its adjacent boundaries. Life size. (The vertebrae are the third and fourth lumbar.)

A—Inferior articular process of upper vertebra.
B—Root (pedicle) of upper vertebra.
C—Body of upper vertebra.
D—Intervertebral fibro-cartilage.
E—Body of lower vertebra.
F—Root (pedicle) of lower vertebra.
G—Superior articular process of lower vertebra.

Inferior.

Cervical, Thoracic, and Upper Lumbar	Root (pedicle) of lower vertebra.
Lower Lumbar	Root of lower vertebra. Transverse process of lower vertebra.

In the upper part of the lumbar region the transverse processes arise from the junction of the laminae and roots (pedicles), but descending they advance taking their origin from the lateral surface of the roots and finally from the sides of the bodies as well. This arrangement explains why the superior and inferior boundaries of the lower lumbar intervertebral foramina are partly formed by the transverse processes.

The boundaries of the intervertebral foramina are smooth. They are covered by periosteum, capsular ligaments connecting the articular processes, the posterior longitudinal (posterior common) and lateral vertebral ligaments covering the vertebral bodies, and the intervertebral fibro-cartilages.

The anterior and posterior boundaries of the intervertebral foramina in the thoracic and lumbar regions are in the same sagittal plane on account of the articular processes and bodies of the vertebrae projecting equi-laterally. The superior and inferior boundaries are also in the same sagittal plane on account of the roots (pedicles) projecting directly posteriorly from the lateral extremities of the bodies. In the cervical region the roots project laterally as well as posteriorly, with the result that the articular processes are more laterally situated than are the bodies, and the various boundaries are not in the same sagittal plane. Therefore the intervertebral foramina are all directed laterally except in the cervical region. Here they are directed antero-laterally.

Due to the peculiar arrangement of the transverse and articular processes in the cervical region, the bony relations lateral to the intervertebral foramina form directly continuous, incomplete, osseous

canals, through which pass the spinal nerves and vessels. Like the cervical intervertebral foramina they are directed antero-laterally.

In the lumbar region the bony boundaries of the intervertebral foramina are so massive that they might be considered as osseous canals. This is especially true in the lower lumbar region where the transverse processes assist in forming the superior and inferior boundaries.

III. SHAPE AND RELATIVE SIZE OF THE INTERVERTEBRAL FORAMINA

Shape. The shapes of the intervertebral foramina in the several regions are distinctive from one another, but all in each region are similar. However they are all more or less oval with the greatest diameter in a supero-inferior direction. The largest antero-posterior diameter of the cervical intervertebral foramina is through the middle; of the thoracic and lumbar, through the upper part. Their respective shapes can be best understood by a study of Plate 4.

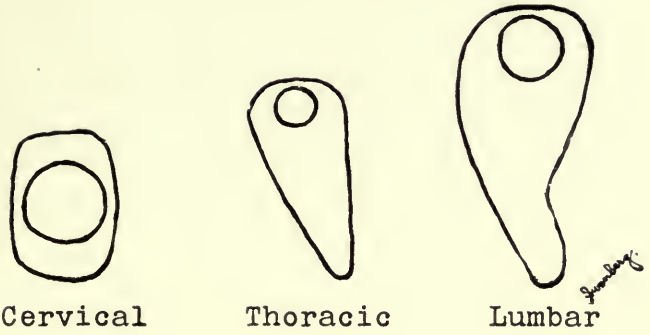
Relative Size. On account of their shapes it is very difficult to estimate accurately the comparative sizes of the intervertebral foramina. However the cervical and upper thoracic foramina are approximately of equal size and are about 10 mm. (⅖ in.) in their greatest diameter. Beginning with the middle thoracic region they gradually increase in size from above downward to the fourth lumbar, the largest foramina being those of the middle lumbar region, which are about 18 mm. (¾ in.) in their greatest diameter. The fifth lumbar intervertebral foramina are not the largest pair as is commonly thought, as the comparative thinness of the posterior part of the fifth lumbar vertebral body and corresponding intervertebral fibro-cartilage greatly reduces their supero-inferior diameter. The intervertebral foramina are subject to changes in size and shape, depending upon the position of the vertebral column. Their size is de-

pendent to a very great extent upon the condition of the ligaments and muscles connecting the vertebrae; particularly upon the thickness of the intervertebral fibro-cartilages and the articular cartilage on the articular processes, especially the former.

In order that the reader may have a better understanding of the size of the intervertebral foramina, the following measurements of the supero-inferior diameter (greatest diameter), which were taken from the vertebral column of a male adult, are given. This column was of normal length, 75 cm. (30 in.), and devoid of any pathologic curvatures.

Intervertebral Foramen	Supero-Inferior Diameter	Intervertebral Foramen	Supero-Inferior Diameter
3 C.	10.5 mm.	7 T.	13.5 mm.
4 "	8.5 "	8 "	14. "
5 "	9.5 "	9 "	14. "
6 "	10. "	10 "	14. "
7 "	10. "	11 "	15. "
8 "	10. "	12 "	16. "
1 T.	10. "	1 L.	18. "
2 "	10. "	2 "	19. "
3 "	10. "	3 "	18. "
4 "	11. "	4 "	17.5 "
5 "	13. "	5 "	12. "
6 "	13. "		

Intervertebral Fibro-Cartilages. The intervertebral fibro-cartilages are twenty-three in number. They are compressible discs of white fibrous tissue and fibrous cartilage, tough but elastic, which are interposed between the bodies of the vertebrae from the epistropheus (axis) to the sacrum and assist in forming the anterior boundaries of all the intervertebral foramina. Similar fibro-cartilages are found between the segments of the sacrum and coccyx in the younger stages of life, but they undergo ossification



The size and shape of a cervical, thoracic and lumbar intervertebral foramen and the position and size of the spinal nerves they convey. The intervertebral foramina shown are the sixth cervical, seventh thoracic and second lumbar. (2 diameters.) Outline drawing.

at their surface and often throughout their whole extent soon after puberty. The intervertebral fibro-cartilages form the chief bond of union between the vertebrae, corresponding in shape with the bodies of the vertebrae they unite. The elasticity of the vertebral column is dependent to a considerable extent upon them. They tend to restore the column to its natural curvature after it has been deflected by muscular action.

In thickness the intervertebral fibro-cartilages vary not only in the different regions of the vertebral column but in different parts of the same disc. This variation in different parts of the same fibro-cartilage contributes much to the formation of the natural curvatures of the vertebral column. In the cervical and lumbar regions they are thicker in front than behind, thereby producing the anterior convexity of the cervical region, and increasing that of the lumbar region. In the thoracic region they are slightly thinner in front than behind, thereby increasing to a small extent the anterior concavity of this region.

Measuring along their anterior surface the intervertebral fibro-cartilages average between 4 and 5 mm. (⅕ in.) in the cervical and thoracic regions and about 13 to 14 mm. (½ in.) in the lumbar region. The thinnest intervertebral fibro-cartilages are from the third to the seventh thoracic vertebrae, measuring from 2 to 3 mm. (⅛ in.); the thickest is between the fifth lumbar and sacrum, and is much thicker in front than behind, being about 18 mm. (¾ in.) on its anterior surface and about one-half this thickness on its posterior surface. The latter fibro-cartilage, due to its wedge-like shape, greatly aids in the formation of the prominent angle situated at the lumbo-sacral junction called the *promontory* (sacro-vertebral angle). The intervertebral fibro-cartilages form nearly one-quarter of the entire length of the vertebral column.

In order that the reader may have a better understanding of the thickness of the intervertebral fibro-cartilages, the following measurements, which were taken from the vertebral column above mentioned, are given. The thickness of each intervertebral fibro-cartilage was measured in the median plane on (1) its anterior surface, (2) its median cut surface and (3) on its posterior surface.

Intervertebral Fibro-Cartilage	Anterior Surface	Median Cut Surface	Posterior Surface.
3 C.	4.5 mm.	5. mm.	4. mm.
4 "	5. "	5. "	2.5 "
5 "	5.5 "	5.5 "	3. "
6 "	5. "	4.5 "	2. "
7 "	3.5 "	4.5 "	2.5 "
8 "	3.5 "	5.5 "	3. "
1 T.	3. "	5.5 "	3.5 "
2 "	2.5 "	5.5 "	3. "
3 "	2. "	6. "	3.5 "
4 "	2. "	5. "	2. "
5 "	2. "	4.5 "	2.5 "
6 "	2.5 "	4. "	2.5 "
7 "	3. "	3. "	2. "
8 "	4.5 "	4. "	2. "
9 "	4.5 "	5. "	2.5 "
10 "	7. "	5. "	3.5 "
11 "	8. "	5.5 "	4. "
12 "	10. "	6. "	4.5 "
1 L.	11. "	9.5 "	7. "
2 "	12. "	12. "	7.5 "
3 "	14. "	14. "	8. "
4 "	17.5 "	15. "	10. "
5 "	19. "	13.5 "	7.5 "

Articular Cartilages. An articular cartilage is found on each articular process of all the vertebrae. It is composed of hyaline cartilage and corresponds in size and shape with the articular part of the process upon which it is situated. It covers the entire area of that part of the articular process which articulates with its fellow. Each cartilage is less than 1 mm. (1/25 in.) in thickness and adheres very closely to the bone.

IV. MODIFIED INTERVERTEBRAL FORAMINA

There are seven pairs of what may be called *modified intervertebral foramina;* two in the cervical, and five in the sacral region. The only point in which they all differ from the intervertebral foramina is that there is no intervertebral fibro-cartilage in connection with them.

The two pairs of modified cervical intervertebral foramina are situated between the occipital bone and the posterior arch of the atlas, and the posterior arch of the atlas and the laminae of the epistropheus (axis), respectively. They are very incompletely surrounded by bone, are directed in a lateral manner, and are converted into more or less definite spaces by the assistance of the soft tissues. These spaces are subject to changes in size and shape with movements of this portion of the vertebral column.

Of the five pairs of modified intervertebral foramina in the sacral region, the upper four are situated between the rudimentary sacral vertebrae. They are completely surrounded by bone and being permanent in size and shape, are not influenced by changes in position of this region of the vertebral column. Due to the fusion of all the sacral vertebrae to form a single bone, osseous canals are formed with which these foramina are continuous; the openings of which on the anterior surface of the sacrum are called the *anterior sacral foramina,* and on the posterior surface, the *posterior sacral foramina.* The posterior foramina are less regular in

form, much smaller in size and their margins much sharper than the corresponding anterior foramina. The last pair of sacral modified intervertebral foramina is situated between the sacrum and coccyx. Between these bones a thin fibro-cartilaginous disc is interposed. These foramina are not entirely surrounded by bone, the fibro-cartilaginous disc and soft tissues completing the boundary, therefore they are subject to changes in size and shape, with the vertebral movements of this region. They are also, as are the first four sacral pairs, divided anteriorly and posteriorly. The sacral foramina decrease in size from above downward.

The anterior rami (anterior primary divisions) of the sacral spinal nerves pass through the anterior sacral foramina; the posterior rami (posterior primary divisions) through the posterior sacral foramina.

Arteries enter and veins emerge from the anterior sacral foramina. Both arteries and veins emerge from the posterior sacral foramina.

V. CONSTITUENTS OF THE INTERVERTEBRAL AND MODIFIED INTERVERTEBRAL FORAMINA

Each intervertebral and modified intervertebral foramen has the following constituents:

1. Spinal Nerve.
2. Arteries.
3. Veins.
4. Fat Tissue.
5. Fibrous Tissue
6. Probably Lymphatics.

1. SPINAL NERVES

In the intervertebral and modified intervertebral foramina the nervous structures present are the spinal nerves.

(a) Anatomy.

Thirty-one pairs of spinal nerves connect the spinal cord with the periphery. Twenty-three pairs pass through the intervertebral foramina; seven pairs, through the modified intervertebral foramina; and the remaining pair, the coccygeal nerves, emerges from the inferior aperture of the sacral canal. Each nerve is composed of *roots, spinal nerve proper,* and *anterior, posterior,* and, as a rule, *meningeal rami.*

Roots. Each spinal nerve is attached to the spinal cord by two roots, an *anterior root* (motor or efferent) and a *posterior root* (sensory or afferent). The origin of the anterior root is in

the gray matter of the spinal cord; its emergence is by several filaments from the antero-lateral surface (anterior root zone). The origin of the posterior root is in the *spinal ganglion,* an oval enlargement which is part of the root; its entrance into the spinal cord is by several filaments through the postero-lateral sulcus.

Spinal Nerve Proper. The anterior and posterior roots of each spinal nerve unite to form the *spinal nerve proper.* This union takes place either in the intervertebral foramen or immediately lateral to it.

Rami. After passing a variable distance each spinal nerve bifurcates, lateral to the intervertebral foramen, into an *anterior* and *posterior ramus* (anterior and posterior primary division), giving off, just before its bifurcation, a very small *meningeal ramus* (recurrent branch). In connection with the anterior ramus or spinal nerve proper, a sympathetic branch is found called the *ramus communicans.*

(b) Relative Size.

The size of the spinal nerves varies greatly. The smallest nerves are connected with the two extremities of the spinal cord and with the mid-thoracic region. The coccygeal nerve is the smallest and the next in order of size are the lower sacral and the upper cervical. The largest nerves are connected with the cervical and lumbar enlargements of the spinal cord and innervate the upper and lower limbs, respectively; the lower cervical and first thoracic for the upper limbs; the lower lumbar and upper sacral for the lower limbs. Of these, the nerves destined for the lower limbs are the larger. The sixth cervical nerves are the largest innervating the upper limbs; either the fifth lumbar or first sacral nerves are the largest innervating the lower limbs, each of the two latter measuring about 7 mm. (2/5 in.) in diameter.

being the largest of all the spinal nerves. The nerves gradually increase in the series passing from the smaller toward the larger.

Roots. The roots correspond in size with the spinal nerves of which they are a part. (The relative size of the spinal nerves is given above.) With the exception of the first cervical nerve, the posterior root is always larger than the corresponding anterior one, indicating that the sensory area to be supplied is greater and perhaps more aburdantly innervated than the motor area. The size of the *spinal ganglion* is in proportion to that of the posterior root of which it is a part.

Spinal Nerve Proper. The spinal nerve proper corresponds in size with the spinal nerve of which it is a part.

Rami. The *anterior rami* (anterior primary divisions) usually correspond in size with the spinal nerves of which they are a part. Therefore the anterior ramus of the coccygeal is the smallest and of the fifth lumbar or first sacral, the largest. With the exception of the first and second cervical nerves, the anterior rami are considerably larger than the corresponding posterior rami.

With one or two exceptions the *posterior rami* (posterior primary divisions) are all very small. The posterior ramus of the second cervical is the largest, following which the rami in the cervical region decrease from above downward. The posterior rami of the thoracic nerves usually vary but slightly in size, while those of both the lumbar and sacral regions decrease from above downward. The smallest posterior ramus is that of the coccygeal nerve.

The *meningeal rami* (recurrent branch) and the *rami communicantes* are all very small.

(c) Location and Divisions in the Intervertebral Foramina.

The spinal nerves in the intervertebral foramina are, more or less, embedded in fat tissue and are situated in the largest part of the foramina; therefore, in the cervical region

they are in the middle part, in the thoracic and lumbar regions, in the upper part.

The divisions of the spinal nerves that may be found in the intervertebral foramina are the roots, the spinal ganglion of the posterior root being included, the spinal nerve proper, and the meningeal ramus (recurrent ramus).

The meningeal ramus is very small and often difficult to find in ordinary dissections. It is given off from the spinal nerve just before it bifurcates into the anterior and posterior ramus (anterior and posterior primary divisions). It joins with a branch from the sympathetic, passes medially and enters the intervertebral foramen through which it reaches the vertebral canal. There it supplies the spinal cord and its membranes, the blood vessels of each, the vertebral ligaments and the vertebrae. At times the meningeal ramus is probably absent altogether, its place being taken entirely by the meningeal fibers passing in the substance of the anterior root.

The sympathetic nerve fibers, which form the white rami communicantes, pass through certain intervertebral and modified intervertebral foramina. They are conveyed by all the thoracic intervertebral foramina; the first two or three lumbar; and the second and third, or third and fourth, modified sacral intervertebral foramina. There are probably some conveyed through the third, fourth and fifth cervical intervertebral foramina.* Sympathetic nerve fibers, which are derived from the gray rami communicantes, pass through all the intervertebral and modified intervertebral foramina. All the sympathetic fibers are situated in the substance of the spinal nerves in their passage through the foramina.

*These fibers accompany the phrenic nerve.

2. ARTERIES

Arteries enter the intervertebral and modified intervertebral foramina. As a rule one artery of fair size passes to each foramen. This is known as the *spinal artery*. However in the foramina, several arteries of different sizes are usually seen. These are, in all probability, branches from the spinal artery. The disposition of all the spinal arteries is practically the same. Their function is to supply the contents and wall of the vertebral canal. (The only other source of arterial blood to the vertebral canal is from the anterior and posterior spinal branches of the vertebral artery.) The spinal arteries are arranged similarly on both sides of the vertebral column and are derived from the *vertebral, ascending cervical,* and *deep cervical* arteries in the cervical region; from the *superior intercostal, intercostal,* and *subcostal* arteries in the thoracic region; from the *lumbar* and *ilio-lumbar* arteries in the lumbar region; and from the *superior* and *inferior lateral sacral* and *middle sacral* arteries in the sacral region.

The spinal arteries in the several regions are derived as follows:

Cervical Region.

1. Vertebral, branch of subclavian.
2. Ascending cervical, branch of inferior thyroid.
3. Deep cervical, branch of costo-cervical trunk (superior intercostal).

The vertebral artery, itself, enters the modified intervertebral foramen situated between the occipital bone and the atlas. Five or six spinal branches are given off from the vertebral artery,

the first one entering the modified intervertebral foramen between the atlas and epistropheus (axis) and the remaining entering the first four or five intervertebral foramina below; one or two are given off by the ascending cervical which enter the middle cervical intervertebral foramina; and one is given off by the deep cervical which enters the last cervical intervertebral foramen.

Thoracic Region.

1. Superior intercostal, branch of costo-cervical trunk.
2. Posterior division of the intercostals, branches of thoracic aorta.
3. Posterior branch of subcostal, branch of thoracic aorta.

From the superior intercostal artery two spinal branches are given off which enter the first and second thoracic intervertebral foramen, respectively; from the posterior divisions of the nine intercostal arteries, spinal branches are given off which enter the intervertebral foramina, from the third to the eleventh, inclusive; and from the posterior branch of the subcostal artery one spinal branch is given off which enters the last thoracic intervertebral foramen.

Lumbar Region.

1. Posterior branch of the lumbars, branches of abdominal aorta.
2. Lumbar division of the ilio-lumbar, branch of hypogastric (internal iliac).

From the posterior branches of the four lumbar arteries spinal branches are given off which enter the first four lumbar intervertebral foramina, and from the lumbar division of the ilio-lumbar one spinal branch is given off which enters the last lumbar intervertebral foramen.

Sacral Region.

1. Superior lateral sacral } Branches of hypogastric
2. Inferior lateral sacral } (internal iliac).
3. Lateral sacral branches of the middle sacral, branch of abdominal aorta.

The superior lateral sacral artery, itself, enters the first anterior sacral foramen. From the inferior lateral sacral artery three spinal branches are given off which enter the second, third and fourth anterior sacral foramen, respectively; and from the lateral sacral branches of the middle sacral four spinal branches are given off which enter the first four anterior sacral foramina, respectively. All the arteries in this region enter the anterior sacral foramina and, after supplying branches to the sacral canal and its contents, emerge by the corresponding posterior sacral foramina.

All of the arteries, with one exception, which give off branches that enter the intervertebral or modified intervertebral foramina are paired; e. g., there are two vertebral arteries, one on each side; two deep cervical arteries, one on each side, etc. The exception is the middle sacral artery which is single.

Two pairs of modified intervertebral foramina have named arteries entering them, the foramina between the occipital bone and atlas, which serve to transmit the vertebral arteries and the first anterior sacral foramina which serve to transmit the superior lateral sacral arteries. These two arteries are of good size, the vertebral being much the larger.

3. VEINS

Veins emerge from the intervertebral and modified intervertebral foramina. Usually one or more are present in each foramen, and are known as the *intervertebral veins.* They convey blood from the *internal vertebral venous plexuses,* and after emerging from the foramina, receive numerous branches from the *external vertebral venous plexuses* and open into the *vertebral vein* and *venous plexus* in the cervical region; into the *intercostal* and *subcostal* in the thoracic region; into the *lumbar* and *ilio-lumbar* in the lumbar region; into the *anterior sacral venous plexus* in the sacral region.

The arrangement is similar on both sides of the vertebral column.

Internal Vertebral Venous Plexuses.

The internal vertebral venous plexuses are located in the vertebral canal. They receive the venous blood from the contents and wall of the vertebral canal. Most of this blood is drained by the *intervertebral veins,* although some is conveyed above by the cranial venous sinuses and also through the ligamenta flava (ligamenta subflava) to the *posterior external vertebral venous plexus.*

Vertebral Vein and Venous Plexus, Intercostal, Subcostal, Lumbar and Ilio-Lumbar Veins and the Anterior Sacral Venous Plexus.

These veins and venous plexuses are situated in the immediate vicinity of the vertebral column in their respective regions. They receive the intervertebral veins and terminate as follows:

Cervical Region. The vertebral plexus of veins is situated in the upper part of the neck terminating as it descends in a single vein, the vertebral vein, which empties into the *subclavian.*

Thoracic Region. The first eleven are the intercostal veins. The remaining one is the subcostal. On the **right** side the first intercostal terminates in the *right vertebral* or *innominate;* the second, third and fourth in the *right superior intercostal;* the fifth to the eleventh, inclusive, with the subcostal, in the *azygos* (vena azygos major). On the **left** side the first intercostal terminates in the *left vertebral* or *innominate;* the second, third and fourth (sometimes), in the *left superior intercostal;* the fourth (sometimes), fifth, sixth, seventh and eighth in the *accessory hemiazygos* (vena azygos minor superior); the ninth, tenth, eleventh and subcostal in the *hemiazygos* (vena azygos minor inferior).

Lumbar Region. The first four are the lumbar veins which terminate in the *inferior vena cava.* The remaining one is the ilio-lumbar vein which terminates in the *common iliac.*

Sacral Region. The sacral intervertebral veins emerge from the anterior sacral foramina, none passing from the posterior foramina. The anterior sacral venous plexus, previously mentioned, is formed by the superior and inferior lateral sacral and the middle sacral veins. The first sacral intervertebral vein is drained by the superior lateral and the middle sacral veins; the second, third and fourth veins by the inferior lateral and the middle sacral veins. The superior and inferior lateral sacral veins terminate in the *hypogastric* (internal iliac), and the middle sacral in the *left common iliac.*

The arrangement of the veins corresponds in general with that of the arteries. All are paired except the middle sacral which, like its corresponding artery, is single.

4. FAT TISSUE

Considerable fat tissue is found in the intervertebral and modified intervertebral foramina and the immediate surrounding parts. It forms the most abundant constituent of the epidural cavity of the vertebral canal and the intervertebral foramina. As the nervous structures, which are more or less embedded in the fat tissue, pass from the spinal cord, the fat tissue in their immediate vicinity gradually decreases in amount.

It is well to remember that a small amount of fibrous tissue is a normal constituent of all fat. Fat cells are developed directly from embyronic connective tissue cells. The embryonic connective tissue cells of developing fat which are not destined to become fat cells, develop into cells and fibers of ordinary fibrous tissue (intralobular connective tissue). A few of these cells and fibers remain among the fat cells and are seen as such in adult fat, but the majority unite to form septa of fibrous tissue (interlobular connective tissue) which arrange the fat into groups or lobules.

While it is true that fat tissue practically always has some fibrous tissue in connection with it, the reverse of this is not true.

5. FIBROUS TISSUE

There is very little fibrous tissue present in the epidural cavity of the vertebral canal and the intervertebral and modified intervertebral foramina, but laterally it is much more abundant. Most of the fibrous tissue present is in association with fat tissue. As the nervous structures pass from the spinal cord the fibrous tissue in their immediate vicinity gradually increases in amount. The entire vertebral column is practically surrounded by fibrous and muscular tissue.

The fibrous tissue present in the vicinity of the intervertebral foramina is very abundant and consists of the vertebral ligaments, including the intervertebral fibro-cartilages, the periosteum of the vertebrae and ribs, epineurium of the nervous structures, epimysium of surrounding muscles, capsules of lymph nodes, walls of blood and lymph vessels, the surrounding fasciae and membranes, and connects the dura mater to the posterior longitudinal ligament (posterior common ligament).

6. LYMPHATICS

Little is known concerning the lymphatics present in the intervertebral and modified intervertebral foramina. In the ordinary stained histologic section no lymph vessels can be recognized. Their presence or absence can only be proved by special injection methods. No lymph vessels are present in the spinal cord. However, like nearly all parts of the body, it has a lymph supply, the nerve cells being more or less bathed by lymph contained in pericellular lymph spaces.

Perivascular lymph spaces or channels convey lymph from the spinal cord. In all probability the lymph passes through the intervertebral foramina in these spaces and definite lymph vessels and glands are not formed until lateral to them.*

*The only lymphatic structures that can be recognized as such in the plates in this text are sections through lymph nodes lateral to the intervertebral foramen. (Plates 8, 9, 10.)

VI. SIZES OF THE INTERVERTEBRAL FORAMINA AS COMPARED TO THE SPINAL NERVES

The intervertebral foramina in each region increase in size from above downward but the spinal nerves which they transmit do not increase in the same manner and therefore will not be proportionate. For example: The middle thoracic intervertebral foramina are larger than the lower cervical foramina, yet the middle thoracic spinal nerves are much smaller than the lower cervical nerves. (Plate 4.) The greatest proportion, the author has observed, was where about one-third of the total area of the intervertebral foramen was occupied by the spinal nerves; the smallest, by about one-twelfth. The intervertebral foramina are largest in proportion to the nervous structures, in the middle and lower thoracic regions and smallest in the lower cervical region. Although the thoracic region, as a whole, has the least movement of the movable regions of the vertebral column, the nerves here appear best protected. Almost the reverse is true of the cervical region. However in each region of the vertebral column there is ample room for the passage of all the structures through these apertures. The sizes of the intervertebral foramina as compared to the spinal nerves is also dependent to a considerable extent upon the part of the spinal nerves present in the foramina. If the anterior root and the spinal ganglion of the posterior

root are present in the intervertebral foramen, they will occupy a greater area than when the spinal nerve proper is present. It appears that the intervertebral foramina are larger in proportion to the spinal nerves they convey, in the normal adult than in the child, although it has not been definitely proven. The reason for this belief is as follows: At birth the spinal cord extends in the vertebral canal to as low as the level of the body of the third lumbar vertebra; in the adult it extends only to the level of the body of the first lumbar. This means that the vertebrae, which in all probability includes the intervertebral foramina, grow more rapidly than does the cord. If the spinal nerves grow in proportion to the growth of the cord, which is very plausible, it appears evident that the intervertebral foramina grow faster than the nerves.

PART II

DETAILED DESCRIPTION OF AN INTERVERTEBRAL FORAMEN AND ITS ADJACENT PARTS

INTRODUCTION

The necessary specimen was secured from a five-month-old male infant. At this age the intervertebral foramina are of such size as to be very suitable for microscopic examination. The infant had been normal in every respect until eight days prior to its death. At this time it developed a broncho-pneumonia.

The right seventh thoracic intervertebral foramen was selected for study. The right half of the seventh and eighth thoracic vertebrae, with the head and neck of the right seventh and eighth ribs attached, was used as a specimen. The specimen was put through the usual histologic technique, the bones being decalcified with dilute nitric acid. It was placed and mounted on a block, the longitudinal cut surface of the spinal cord and the bodies and laminae of the vertebrae, resting on the block. The specimen was then cut into sections, approximately in the sagittal plane, forty-nine sections in all being preserved, there being an average of about 180 microns (1/140 in.) between each. They were cut from without inward, and labeled accordingly. These sections cut the spinal nerve almost transversely as it emerged from the intervertebral foramen. Section 1 shows structures considerably lateral to the intervertebral foramen, while Section 49, the last one, is in the vertebral canal. Photomicrographs of only four of these sections (Sections 38, 30, 27, 23) are given in this description.

General Description of Plates. Plates 5 and 6 are drawings which are shown that the reader may better understand the photomicrographs which follow.

Plates 7, 8, 9, and 10 are retouched photomicrographs of the right seventh thoracic intervertebral foramen and the area lateral to it. Each is enlarged about 10 diameters. In the retouching no attempt was made to conceal the results of faulty technique, thus every part is shown to be practically identical with the original slides. Each plate corresponds to a section and is numbered in the reverse order (within outward) from which the section was cut. Plate 7, the first photomicrograph, is Section 38 which cuts through the intervertebral foramen; and the remaining plates, 8, 9, and 10, are Sections 30, 27, and 23 respectively, which are lateral to the intervertebral foramen.

The photomicrographs in this text show the following nervous structures:

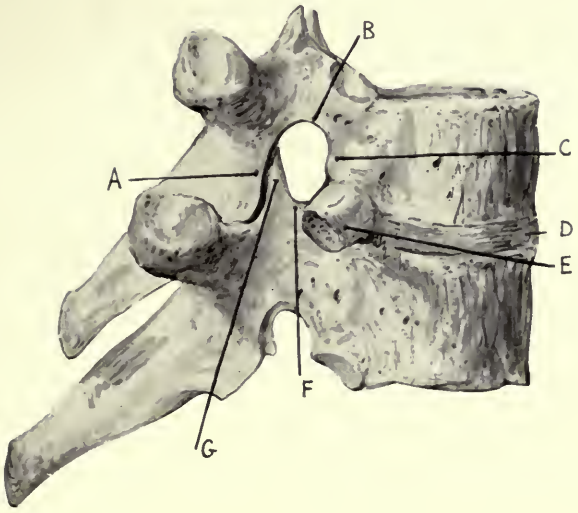
1. Anterior and posterior roots; spinal ganglion on posterior root;
2. Spinal nerve proper;
3. Anterior and posterior rami (anterior and posterior primary divisions);
4. White and gray rami communicantes of the sympathetic;
5. Ganglion of the sympathetic gangliated trunk.

DESCRIPTION OF PLATE 5

This plate shows the right lateral view of the seventh thoracic intervertebral foramen, together with the seventh and eighth thoracic vertebrae, with the intervertebral fibro-cartilage connecting them, and the head and neck of the right eighth rib.

Bony Boundaries of Intervertebral Foramen.

Anterior	Body of seventh thoracic..
	Head of eighth rib.
	(The external lateral part of the seventh thoracic intervertebral fibro-cartilage also forms an anterior boundary, but this is not shown here, it being medial to the head of the rib.)
Posterior	Inferior articular process of seventh thoracic.
	Superior articular process of eighth thoracic.
Superior	Root (pedicle) of seventh thoracic.
Inferior	Root (pedicle) of eighth thoracic.



A right lateral view of the seventh and eighth thoracic vertebrae with the intervertebral fibro-cartilage connecting them, and the head and neck of the right eighth rib. Life size.

A—Inferior articular process of seventh thoracic.
B—Root (pedicle) of seventh thoracic.
C—Body of seventh thoracic.
D—Intervertebral fibro-cartilage.
E—Head of eighth rib.
F—Root (pedicle) of eighth thoracic.
G—Superior articular process of eighth thoracic.

DESCRIPTION OF PLATE 6

This plate is an outline drawing of the right seventh thoracic intervertebral foramen and its adjacent bony boundaries, with the size and position of the roots of the right seventh thoracic spinal nerve. It is shown in detail in Plate 7. The intervertebral foramen has the same bony boundaries, and is in the same position as in Plate 5. Owing to the projection of the bony boundaries at different levels the entire boundary is not always present in each section. In this instance it is deficient inferiorly. The darkened areas represent the hyaline articular cartilage.

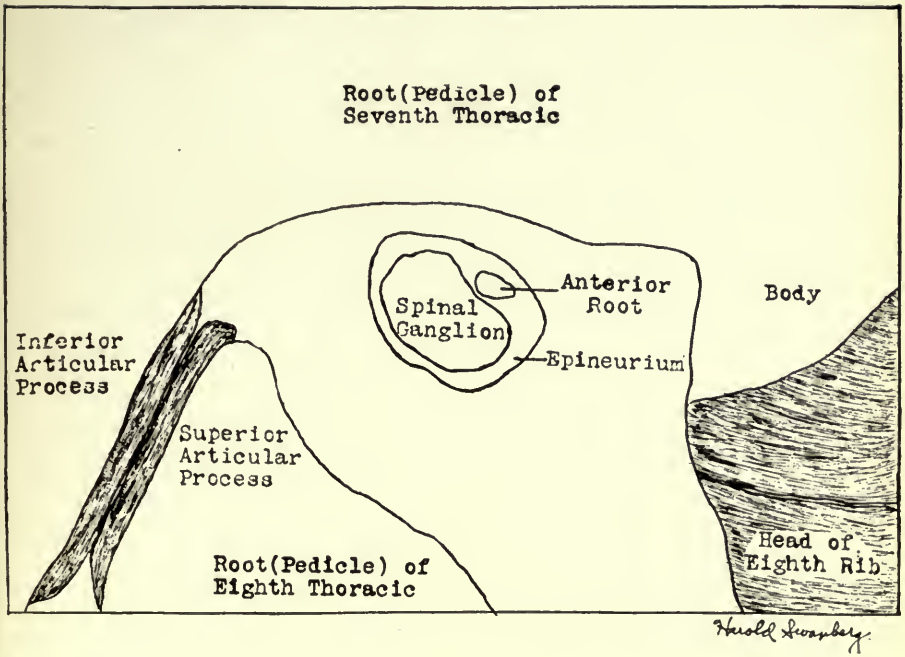
Articular Cartilage on Bony Boundaries.

Hyaline articular cartilage is found on the following parts:

1. Inferior articular process of seventh thoracic.
2. Superior articular process of eighth thoracic.
3. Body of seventh thoracic.
4. Head of eighth rib.

This articular cartilage is found on the articular processes, and on the body of the vertebra and head of rib, where they articulate.

The size and position of the roots of the seventh thoracic spinal nerve are shown in the upper central part of the intervertebral foramen. The small anterior one is the anterior



A right lateral view of the right seventh thoracic intervertebral foramen and its adjacent bony boundaries with the position and size of the roots of the right seventh thoracic spinal nerve. Outline drawing from Plate 7.

root, the large posterior one is the spinal ganglion of the posterior root. The roots are surrounded by epineurium. They occupy about one-fifth of the total area of the intervertebral foramen and are free from any bony contact. The other structures in the foramen, fat cells, fibrous tissue, and blood vessels, are shown in the photomicrographs which follow.

DESCRIPTION OF PLATE 7 (Section 38)

This plate is the most medial one shown in this series and presents a right lateral view of the right seventh thoracic intervertebral foramen and its adjacent bony boundaries. It is in the same position as Plates 5 and 6.

Bony Boundaries of Intervertebral Foramen.

The bony boundaries are similar to those shown in Plates 5 and 6. The reason for the deficiency of the bony boundary inferiorly was given in connection with Plate 6.

Articular Cartilage of Bony Boundary.

The articular cartilages are similar to those shown in Plate 6.

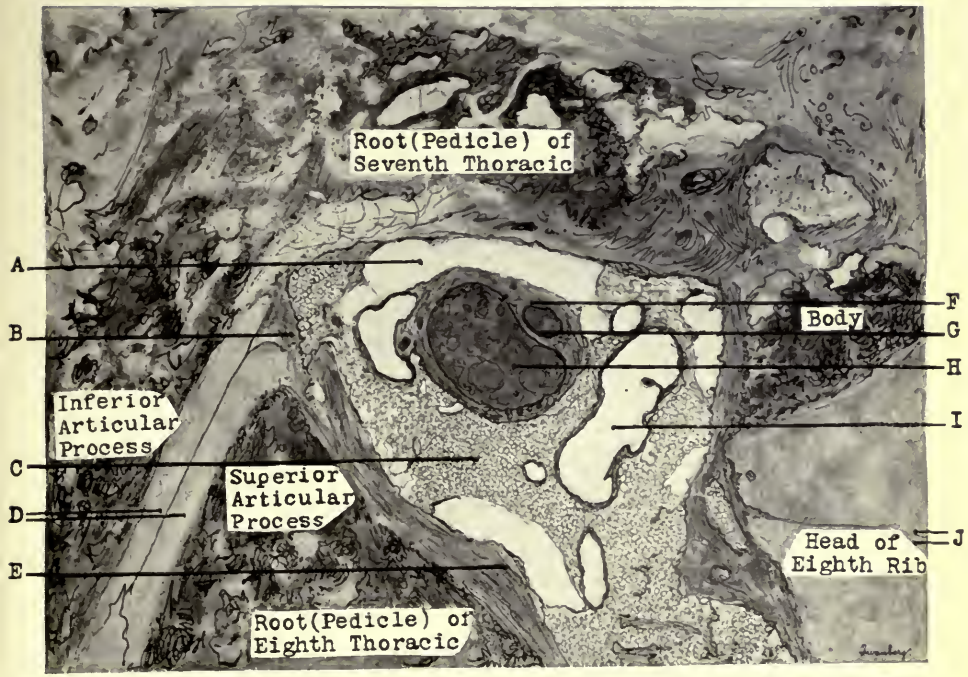
Contents of Intervertebral Foramen.

1. Nervous Structures.
2. Blood Vessels.
3. Fat Tissue.
4. Fibrous Tissue
5. Vacant Spaces

Lymphatics are undoubtedly present in this intervertebral foramen but cannot be recognized in this photomicrograph. (See paragraph on "Lymphatics," Page 52.)

1. Nervous Structures.

Anterior root and the spinal ganglion of the posterior root of spinal nerve.



A right lateral view of the right seventh thoracic intervertebral foramen and its adjacent bony boundaries.

A—Vacant space.
B—Capsular ligament.
C—Fat tissue.
D—Articular cartilages.
E—Fibrous tissue.
F—Epineurium.
G—Anterior root of spinal nerve.
H—Spinal ganglion of posterior root of spinal nerve.
I—Blood vessel.
J—Articular cartilages.

The position of the roots has been discussed in connection with Plate 6. The epineurium surrounds each root separately and also serves to bind them together as a whole. They are free from any bony contact and are embedded in fat tissue.

2. Blood Vessels.

Numerous blood vessels of various sizes are embedded in the fat tissue.

3. Fat Tissue.

Fat forms the most abundant constituent of the foramen.

4. Fibrous Tissue.

Fibrous tissue forms the epineurium of the nervous structures, the periosteum of the bones, and part of the walls of the blood vessels, and is a constituent of the fat tissue. This is true in all the sections. It is well to remember that all fat tissue has more or less fibrous tissue in connection with it. The capsular ligament connecting the articular processes, is composed of fibrous tissue.

5. Vacant Spaces.

Spaces occur in which all tissue is absent. In the photomicrographs these vacant spaces are difficult to distinguish from blood vessels. However in the case of the blood vessels the walls are thick, while in the vacant spaces this is not true. The vacant spaces are, no doubt, due to faulty technique and probably represent areas where fat cells have been washed out in the process of preparing the specimen. The above is true in all the sections.

DESCRIPTION OF PLATE 8 (Section 30)

This is immediately lateral to the right seventh thoracic intervertebral foramen.

Bony Relations Lateral to Intervertebral Foramen.

Anterior { Head of seventh rib.
Head of eighth rib.

Posterior { Inferior articular process of seventh thoracic.
Superior articular process of eighth thoracic.

Superior { Root (pedicle) of seventh thoracic.

In this and in the following photomicrographs the positions of the bony parts are named according to their relations to the cerebro-spinal nervous structures.

The heads of the seventh and eighth ribs are shown instead of the body of the seventh thoracic, and the root (pedicle) of the eighth thoracic has disappeared.

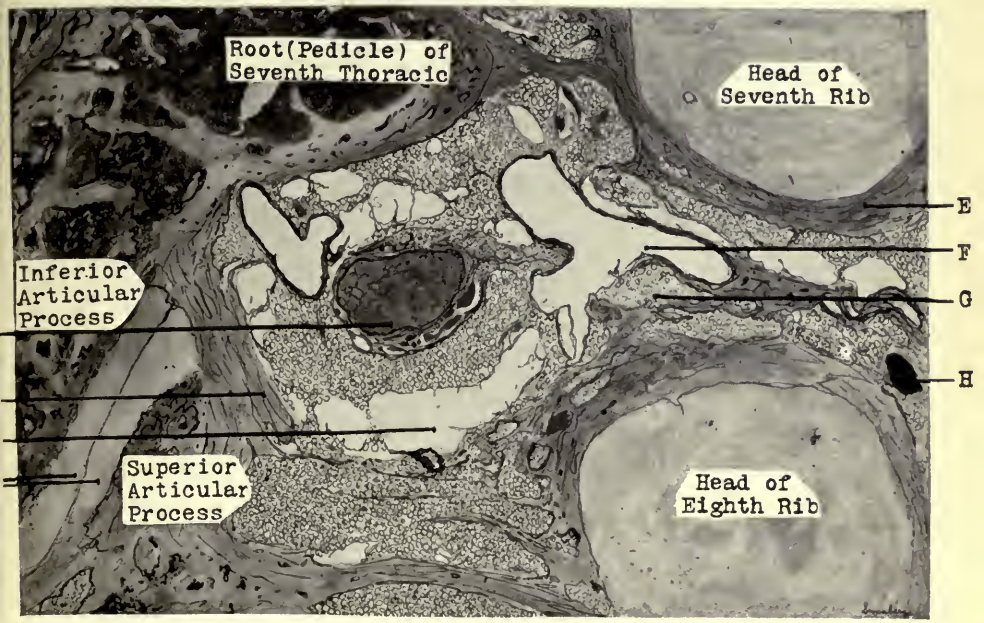
Articular Cartilages.

Articular cartilage is found on the following parts:

1. Inferior articular process of seventh thoracic.
2. Superior articular process of eighth thoracic.

Tissues Lateral to Intervertebral Foramen.

The tissues present are the same as those shown in the former plate except for the addition of lymphoid tissue.



A right lateral view immediately lateral to the right seventh thoracic intervertebral foramen.

A—Spinal nerve.
B—Capsular ligament.
C—Vacant space.
D—Articular cartilages.
E—Fibrous tissue.
F—Blood vessel.
G—Fat cells.
H—Lymph node.

1. Nervous Structures.

The spinal nerve proper.

The anterior and posterior roots seen in the former plate have united and the spinal nerve proper is formed. It is surrounded by epineurium and blood vessels, and is embedded in fat.

2. Blood Vessels.

Numerous blood vessels of various sizes are embedded in fat tissue, as shown in the former plate.

3. Fat Tissue.

Fat is the most abundant tissue present.

4. Fibrous Tissue.

The fibrous tissue is arranged as shown in the former plate except that it appears slightly increased in amount.

5. Lymphoid Tissue.

A lymph node is present anterior to the head of the eighth rib.

DESCRIPTION OF PLATE 9 (Section 27)

This is lateral to the right seventh thoracic intervertebral foramen, lateral to section shown in Plate 8.

Bony Relations Lateral to Intervertebral Foramen.

Anterior { Head of seventh rib.
Head of eighth rib.

Posterior { Inferior articular process of seventh thoracic.

Superior { Root (pedicle) of seventh thoracic.

The superior articular process of the eighth thoracic has disappeared, the articular cartilage only remaining.

Articular Cartilage.

The articular cartilages are the same as shown in the former plate.

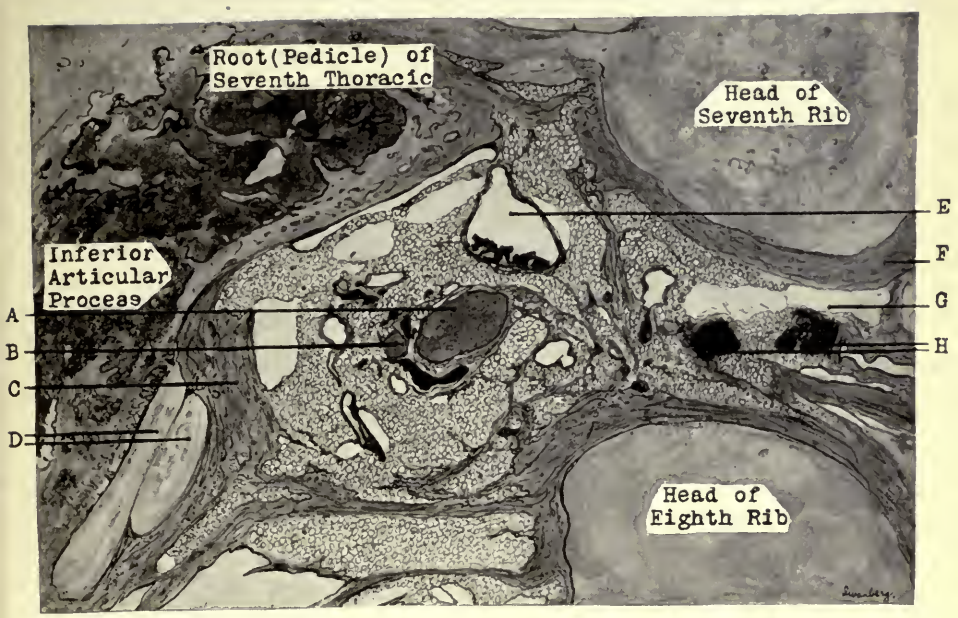
Tissues Lateral to Intervertebral Foramen.

The tissues present are the same as those shown in the former plate.

1. Nervous Structures.

Anterior and posterior rami (anterior and posterior primary divisions) of spinal nerve.

The spinal nerve proper seen in the former plate has



A right lateral view lateral to the right seventh thoracic intervertebral foramen lateral to Plate 8.

A—Anterior ramus (anterior primary division) of spinal nerve.
B—Posterior ramus (posterior primary division) of spinal nerve.
C—Capsular ligament.
D—Articular cartilages.
E—Blood vessel.
F—Fibrous tissue.
G—Vacant space.
H—Lymph nodes.

bifurcated into an anterior and a posterior ramus. As is usual, the anterior ramus is the larger of the two. The rami are separated by fibrous tissue and are embedded in fat.

2. Blood Vessels.

The blood vessels are arranged as in the former plates.

3. Fat Tissue.

Fat tissue is the most abundant tissue present.

4. Fibrous Tissue.

The fibrous tissue is slightly increased in amount.

5. Lymphoid Tissue.

Two lymph nodes are present between the heads of the ribs.

DESCRIPTION OF PLATE 10 (Section 23)

This is lateral to the right seventh thoracic intervertebral foramen, lateral to section shown in Plate 9.

Bony Relations Lateral to Intervertebral Foramen.

Anterior { Neck of seventh rib.
Neck of eighth rib.

Posterior { Transverse process of seventh thoracic.

Superior { Transverse process of seventh thoracic.

The transverse process of the seventh thoracic is shown instead of the root (pedicle) and the inferior articular process of this vertebra. The necks of the ribs are shown instead of the heads.

Articular Cartilages.

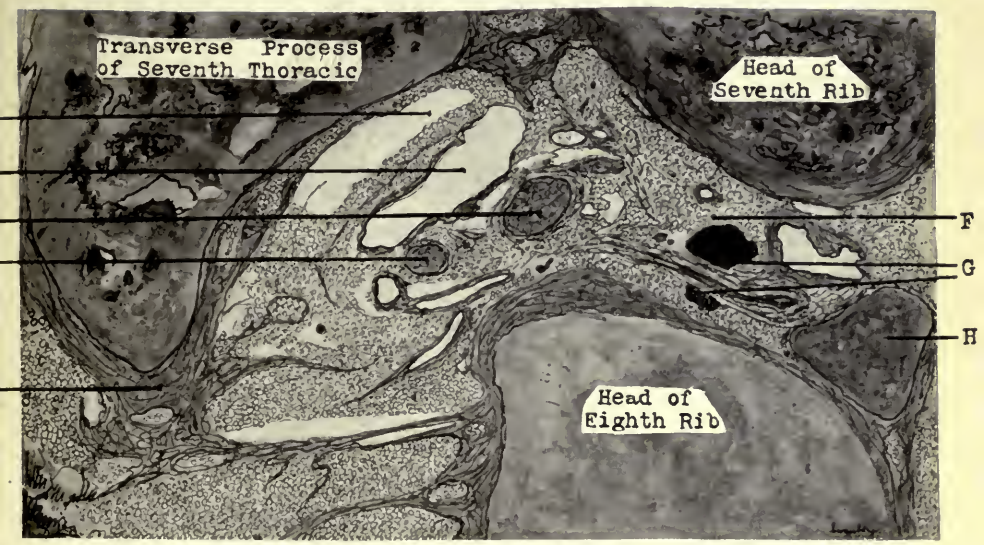
None of the bones present articulate with one another, hence no articular cartilages are present.

Tissues Lateral to Intervertebral Foramen.

The tissues present are the same as those shown in the former plate.

1. Nervous Structures.

Anterior and posterior rami (anterior and posterior primary divisions) of spinal nerve.



A right lateral view lateral to the right seventh thoracic intervertebral foramen lateral to Plate 9.*

A—Vacant space.
B—Blood vessel.
C—Anterior ramus (anterior primary division) of spinal nerve.
D—Posterior ramus (posterior division) of spinal nerve.
E—Fibrous tissue.
F—Fat tissue.
G—Lymph nodes.
H—Sympathetic ganglion of sympathetic trunk.

*The label on each rib should read "neck" instead of "head."

Sympathetic ganglion of the sympathetic trunk.

The rami are embedded in fatty-fibrous tissue. Resting on the anterior surface of the neck of the eighth rib, a sympathetic ganglion is present. Like all nerves, it is surrounded by epineurium. It also is embedded in fatty-fibrous tissue.

2. Blood Vessels.

The blood vessels are arranged as in the former plates, and are embedded in fatty-fibrous tissue

3. Fat Tissue.

Fat remains the most abundant tissue. There is considerable fibrous tissue loosely arranged, in connection with it.

4. Fibrous Tissue.

The fibrous tissue is slightly increased in amount.

5. Lymphoid Tissue.

Two lymph nodes are present between the necks of the ribs.

DESCRIPTION OF PLATE 11 (Special)

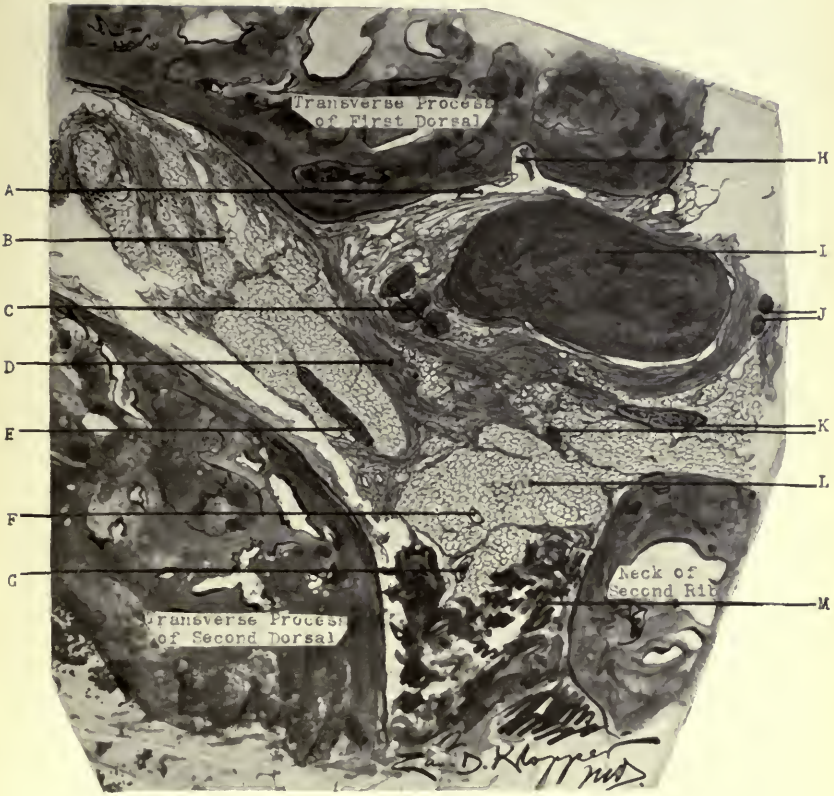
This plate is from the author's book "The Intervertebral Foramen." It is shown here in order that the reader may see the white and gray rami communicantes of the sympathetic. (The above nervous structures are not shown in the foregoing photomicrographs.)

The plate shows a right lateral view lateral to the right first thoracic intervertebral foramen of the cat, and is enlarged about 13 diameters. It is in the same position and has the same relations as the section shown in Plate 10. This intervertebral foramen has the same boundaries as has the seventh thoracic.

The nervous structures present are seen just beneath the transverse process of the upper vertebra. The large anterior one is the anterior ramus (anterior primary division) of the spinal nerve. Several smaller filaments are seen immediately posterior to the anterior ramus. These constitute the posterior ramus (posterior primary division) of the spinal nerve. Embedded in fibrous tissue, anterior to the anterior ramus, two very small nerve filaments, very closely associated, are seen.* These constitute the white and gray rami communicantes of the sympathetic. They connect the anterior ramus with the nearest ganglion of the sympathetic gangliated trunk.

All the nervous structures are embedded in fibrous tissue. This tissue is more dense than that shown in the foregoing plates.

*These findings agree with those of Langley who writes in Schäfer's Physiology: "The uppermost thoracic white and grey rami are too closely associated to be cut separately."



A right lateral view lateral to the right first thoracic intervertebral foramen.

A—Blood vessel.
B—Fatty-fibrous tissue.
C—Posterior ramus (posterior primary division) of spinal nerve.
D—Fibrous tissue.
E—Blood vessel.
F—Blood vessel.
G—Blood vessel.
H—Nutrient foramen.
I—Anterior ramus (anterior primary division) of spinal nerve.
J—White and gray rami communicantes of sympathetic.
K—Blood vessels.
L—Fat cells.
M—Voluntary muscle.

SUMMARY OF THIS INTERVERTEBRAL FORAMEN AND ITS ADJACENT PARTS

Medial to Intervertebral Foramen. Immediately medial to the intervertebral foramen the epidural cavity of the vertebral canal is entered. Although no photomicrographs are shown in this text of the epidural cavity opposite this intervertebral foramen, the following is its structure: It lies between the dura mater and the bony boundaries of the vertebral canal. The most abundant constituent is fat tissue, in fact it is almost completely filled with fat. The roots of the spinal nerve and the blood vessels are embedded in this fat. Very little fibrous tissue is present.*

Intervertebral Foramen. The most abundant constituent of the intervertebral foramen is fat tissue. The roots of the spinal nerve, including the spinal ganglion, which are situated here, are embedded in fat tissue. They occupy about one-fifth of the total area of the foramen. The blood vessels, which are several in number and of various sizes, are embedded in fat tissue. There is a small amount of fibrous tissue present.

Lateral to Intervertebral Foramen. The most abundant constituent is fat tissue. It is, however, infiltrated with a more or less loosely arranged fibrous tissue, making a fatty-fibrous tissue. The spinal nerve proper, the rami (pri-

*In "The Intervertebral Foramen," the author's previous work, photomicrographs of the vertebral canal are shown in Plates 5, 6, 7, and 8.

mary divisions) of the spinal nerve, and the sympathetic ganglion are present. They are all more or less embedded in fatty-fibrous tissue. The blood vessels, which are several in number and of various sizes, as in the intervertebral foramen, are embedded in fatty-fibrous tissue. Several lymph nodes are present.

PART III

SUMMARY

GENERAL SUMMARY

Having spent considerable time, covering a period of over four years, studying various intervertebral foramina, with their contents and adjacent parts, microscopically and macroscopically, both in man and animal, I can briefly summarize my findings concerning the normal morphology of these apertures and parts as follows:

1. All of the intervertebral foramina, including their contents and the areas immediately medial and lateral to them, have a similar structure.

2. They are almost entirely surrounded by bone, the intervertebral fibro-cartilages completing the boundary.

3. In each region they have a characteristic shape, but all are more or less oval, with the greatest diameter in a supero-inferior direction. The greatest antero-posterior diameter in the cervical region is through the middle; in the thoracic and lumbar, in the upper part.

4. In general, they increase in size from above downwards, being smallest in the cervical and largest in the lumbar regions.

5. They are dependent to a great extent, as to size, upon the thickness of the intervertebral fibro-cartilages and the articular cartilage on the articular processes, especially the former.

6. They are subject to changes in size and shape, depending upon the position of the vertebral column.

7. Each intervertebral foramen has the following constituents: (1) spinal nerve, (2) arteries, (3) veins, (4) fat tissue, (5) fibrous tissue, and in all probability (6) lymphatics.

8. The sympathetic nerve fibres which pass through the intervertebral foramina are in the substance of the spinal nerves.

9. The divisions of the spinal nerves that may be found in the intervertebral foramina are the roots, the spinal ganglion on the posterior root being included, the spinal nerve proper, and the meningeal ramus (recurrent ramus).

10. The spinal nerves are situated in the largest part of the intervertebral foramina; therefore in the cervical region they are in the middle part, in the thoracic and lumbar regions, in the upper part.

11. The intervertebral foramina are not proportionate in size to the spinal nerves they convey.

12. They are, for the most part, large, as compared to the spinal nerves which they transmit.

13. The spinal nerves are, as a rule, embedded in fat tissue in the intervertebral foramina.

14. The most abundant constituent of the intervertebral foramina and the areas immediately medial and lateral to them, is fat tissue.

15. Lateral to the intervertebral foramina there is considerable fibrous tissue present. In fact the entire vertebral column is practically surrounded by fibrous and muscular tissue.

16. The fat tissue in the immediate vicinity of the spinal nerves gradually decreases and the fibrous tissue increases in passing from the spinal cord.

17. The nervous structures are embedded in fat tissue in the vertebral canal and the intervertebral foramina; in a more or less loosely arranged fibrous or fatty-fibrous tissue lateral to the intervertebral foramina.

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